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PERMANENT AND TEMPORARY SHOCKS TO GOVERNMENT SPENDING: AN EMPIRICAL APPROACH

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Abstract

Cointegration between government spending and output is rarely considered in fiscal research. Motivated by this potential long-run relationship, the paper focuses on separating temporary from permanent shocks to government spending using a SVECM. In particular, this decomposition reveals that government expenditure data is indeed a mix of stabilisation interventions and responses to economic growth. The interpretation of these shocks is then used to infer the consequences of temporary increases in government spending. Controlling for cointegration delivers results consistent with existent literature, yet the effects seem to be less persistent as the impact on output rapidly converges to zero.

Key Words: Fiscal Policy, Cointegration, Structural VECM Models, Government Spending Shocks

JEL Classification: E600, E620

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I Introduction

Fiscal policy has long been a topic of little consensus among academics. Its nature and the vast range of policy instruments are responsible for several challenges in modelling, namely the understanding for transmission channels. Accordingly, there is still no agreement on a theoretical framework and empirical methodologies often provide contradictory evidence on its aggregate effects. On the other hand, some argue that implementation lags condition fiscal policy: it takes time for policymakers to perceive the economic cycle, formulate measures and put them into place. By the time fiscal policy materialises, the economy may no longer be in the initial situation and, thus, the result may be different from what was expected. As a result, the topic was mostly set aside from discussion.

In the past years, the interest in fiscal policy was renewed. With interest rates falling to their zero lower bound, conventional monetary policy was no longer available. Policymakers turned their attention to fiscal policy, seeking to minimise the negative effects of the Great Recession. At the same time, its overuse originated the Sovereign Debt Crisis in the Euro Area as governments were suffering from sudden stops in credit due to a massive accumulation of public debt. It became imperative the study of the consequences of fiscal policy, both as a stabilisation policy and as a debt consolidation mechanism.

Identifying exogenous fiscal shocks is the main challenge of empirical work due to the inherent endogeneity of fiscal policy and output: fiscal variables also respond to fluctuations in GDP, whether due to discretionary policy or automatic stabilisers. With the purpose of isolating exogenous changes in fiscal policy various methodologies have been used: SVAR (Structural Vector Autoregressions) with short-run restrictions pioneered by Blanchard and Perotti (2002) (followed by Perotti (2005), Perotti (2007), Auerbach and Gorodnichenko (2012) and Ilzetzki et al. (2013)); VAR with signal restrictions as in Mountford and Uhlig (2009); the so-called Narrative Approach as in Romer and Romer (2010), Ramey (2011) and Barro and Redlick (2011); Local projections using the Narrative Approach as in Owyang et al. (2013) and Ramey and Zubairy (2018). In a recent survey, Ramey (2019) concluded that the different empirical studies developed in the past years have estimated spending multipliers concentrated between 0.6 and 1 and tax multipliers between -2 and -3.

The simplest empirical specifications were adapted to account for state dependence as theory predicts that multipliers may depend on several factors like the persistence of shocks, the state of the economy, how the policy is financed, the debt-to-GDP ratio, country openness and the exchange rate regime. The focus has been mainly on understanding if fiscal policy is more effective as a stabilisation policy during periods with higher slack in the economy or accommodating monetary policy. Opposite evidence was found on these issues: Auerbach and Gorodnichenko (2012) show that spending multipliers are higher during recessions using a SVAR identification à la Blanchard and Perotti (2002) in a non-linear model, yet, Barro and Redlick (2011) and Ramey and Zubairy (2018) found no such evidence using the narrative approach.

The work of Christiano et al. (2011) indicates that government spending multipliers can be very large in the presence of unresponsive nominal rates, such as the zero lower bound. However, empirical evidence has also been contradictory on these grounds: while Ramey (2011), Ramey and Zubairy (2018) through the narrative approach found no strong evidence, Ilzetzki et al. (2013) point out that the behaviour of monetary policy is key in determining the strength of fiscal policy, using an identification scheme similar to the one in Blanchard and Perotti (2002).

Ilzetzki et al. (2013) also contributed to the existent literature by studying how several features of countries impact the estimated multipliers. Their evidence suggest that spending multipliers are greater in industrialised countries than in developing countries. Yet, developing countries present investment spending multipliers greater than 1 and different from spending ones, whereas this does not seem to be the case for developed countries. Moreover, under fixed exchange rate regimes, spending multipliers are also higher than in countries under floating regimes. For countries with high debt-to-GDP ratios, multipliers are null and may become negative over time.

Other developments concerning the role of public debt have contributed to a better understanding of the broad range of multipliers estimates. Debt sustainability plays an important part in determining the availability of fiscal policy and the future paths of both government spending and tax policy. Favero and Giavazzi (2007) adapted the usual SVAR model to include debt dynamics, arguing that omitting public debt from the model leads to the extraction of non-fundamental shocks and biased IRF (impulse response functions).

Empirical identification strategies are not flawless. The SVAR approach has been mainly criticised for extracting fiscal shocks which were anticipated by agents. Ramey (2011) found that both Ramey and Shapiro (1999) dates and professional forecasts Granger-cause the shocks obtained using the SVAR approach. Following on this major pitfall of SVAR, Auerbach and Gorodnichenko (2012) included professional forecasts in their model and reinforced Ramey's claim. On the other hand, the narrative approach is largely based on news from military expenditure or defence spending itself, which makes it not reproducible for the majority of countries and raises the issue of extrapolating on the magnitude of non-defence multipliers. Perotti (2005) also raises some questions on the validity of the conclusions taken, pointing that if at the time of the defence news shocks there are other fiscal shocks the effects might be difficult to distinguish.

Other than providing spending and tax multipliers of different magnitudes, the SVAR and narrative approaches also support different economic theories by predicting different behaviours for consumption and real wages. As a result, some effort has been done to try to understand the reasons for these discrepancies. Some of the previously mentioned literature relates state dependence and omitted variables bias to the different estimates. Nonetheless, identification assumptions also seem to play an important role as Caldara and Kamps (2008) and Caldara and Kamps (2012) show that each method entails a different implicit output elasticity with respect to either spending or taxation. Ramey and Zubairy (2018) reproduced the analysis in Auerbach and Gorodnichenko (2012) and reveal that the results are consequences of the assumptions made when computing IRF. Additionally, Ramey (2011) demonstrates that the results in Blanchard and Perotti (2002) are due to expected/announced spending not being controlled for.

Nevertheless, an issue that seems to be overlooked in existent literature is the potential cointegration between output and fiscal variables. The data suggests that the US government expenditure shares a long-run relationship with output, as it is possible to see in figure 1.

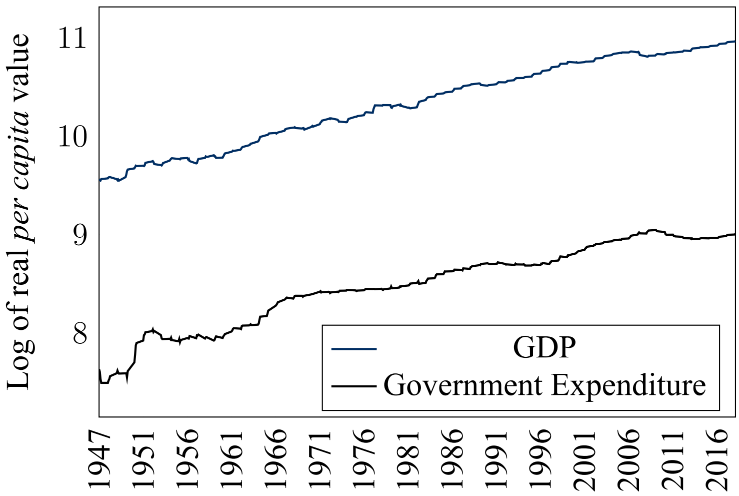

Figure 1: US GDP and Government Expenditure Data, in logs of real *per capita* values

It is a well-accepted fact that GDP is not a stationary variable, however there is still no common view on whether it results from a deterministic trend or a stochastic one. This raises issues on how to better model the behaviour of GDP, and fiscal variables which exhibit similar patterns. Blanchard and Perotti (2002) estimate their SVAR model assuming both specifications, and as expected, even though results are similar, there is some persistence in the results of the stochastic trend model which is not found in the deterministic trend model.

Stationarity tests suggest that GDP, as well as fiscal variables, are not trend stationary, but integrated of order 1, $I(1)$. The usual procedure to deal with this type of variables is considering the model in first differences (like in Blanchard and Perotti (2002)). Yet, in the presence of cointegration, this method not only reduces the set of information available to estimate the model, but it neglects the existence of a long-run relationship. Blanchard and Perotti (2002) argue that considering cointegration does not change the results. However, the cointegration relation studied lies in the argument of a stationary government budget, and therefore only considers spending and revenue. In light of the previous considerations, one must consider the possibility of neither results being accurate.

In Wagner (1892) is found the first theoretical argument supporting a common trend between the size of government and economic growth, the so-called Wagner's Law[2]. The claim relies on citizens demanding more public services and government intervention as the economy becomes more developed. Government expenditure directed at health care, education, law enforcement, sanitation, transportation, among others is likely to increase as the country achieves higher levels of development and economic growth. Moreover, some of these types of spending can affect back output through spillovers on production. Accordingly, there are motives to believe in this long-run relationship, hence reasons to account for it when modelling fiscal policy[3].

This paper attempts to bring some light into an issue not very often considered: cointegration between government spending and output, using a structural vector error correction model (SVECM). The goal is to explore how this new set of information can be used to study the impact of fiscal policy. The rest of the paper is organized as follows. Section II discusses the theoretical framework. Methodology is presented in section III. Section IV elaborates on the empirical model and shows the results. Finally, section V concludes. Further details on data, econometric tests and methodology as well as additional results can be found in the appendix.

[2]This theory states that government size grows more than proportionately to output. In case of this paper, it is considered a proportional relation as exhibited in the data. However, the arguments still hold.

[3]Nonetheless, it does not have to be the case. In fact, not all countries' data depicts this property.

II Framework for the Analysis

As argued before, there is still no consensus view on how to model fiscal policy. With the purpose of guiding the empirical specification and the interpretation of results, it is followed the seminal work of Baxter and King (1993). In this neoclassical model, unexpected temporary increases in government spending might have different effects depending on the persistence of the shock, financing (lump-sum versus distortionary taxation) and the productivity of spending.

In the first stage, government spending increases, decreasing available resources for both consumption and investment, entailing a negative wealth effect. As an optimal decision, agents decrease consumption and leisure as well as investment. Accordingly, labour supply expands, causing real wages to fall and the labour input to increase. Capital markets are affected through the improvement in the productivity of capital, and the real rental rate responds subsequently, leading to an increase in real interest rate. It follows that output rises due to the higher labour input, which cushions part of the fall in consumption. Afterwards, when spending returns to the initial levels, the economy converges back to the initial equilibrium. The key determinant in boosting the economy during the period of higher spending is the expansion in the labour supply. It results that the longer the temporary higher spending lasts, the more negative the wealth effect and the more significant the stimulus to output.

If government spending is productive and affects the marginal productivity of capital and labour inputs, then instead of depressing investment, capital accumulation is stimulated in addition to the increase in the labour force. The economy converges to a higher equilibrium, even with a temporary increase in government spending. This phenomenon is not accounted for in the proposed econometric model as the study focuses on non-productive government spending.

Previous results are, however, dependent on the assumption of lump-sum taxation, which is rare in the real world. Once distortionary taxation is introduced, agents may have incentives to postpone both work and investment. Given a strong intertemporal substitution effect output may decrease. Ultimately, the decision of how to finance the policy plays a vital role in determining the size of spending multipliers since choosing deficit-financing over higher taxes may delay the harmful effects of the distortionary policy.

The new Keynesian model also provides insights on the effects of fiscal policy since it allows for the role of demand, prices and nominal rigidities in the determination of real variables.

For instance, Christiano et al. (2011) show that in this context, a binding zero lower bound can increase significantly the impact of higher government spending. Departing from a significant increase in the discount factor, representing a greater desire for savings, they argue that if the zero lower bound becomes binding before the real interest rate fully adjusts, there must be instead a considerable fall in output. An increase in government expenditure is able to stimulate demand, decreasing firms' mark-up and fuelling expected inflation. Given the inflationary pressures, the real interest rate falls further, promoting consumption today in detriment of consumption in the future, increasing output even further.

Through the analysis of a new Keynesian model in the context of a small open economy, the work of Corsetti et al. (2013) presents evidence against fiscal policy being relatively more effective as a stabilization policy under a fixed exchange rate regime. They argue that accommodating monetary policy can mimic the effects of fiscal policy under a fixed exchange rate regime. On the other hand, fiscal expansions expected to lead to consolidation measures in the medium run have higher multipliers in the context of floating exchange rate regimes.

Galí et al. (2007) have also showed that financial frictions can have significant impacts on the estimated multipliers. By introducing rule-of-thumb consumers in the standard new Keynesian model, consumption can increase as a response to higher government spending, leading to greater effects on output.

III Shocks with Temporary and Permanent Effects

Integrated variables are considered cointegrated when they share the same stochastic trend. This idea has been used in economics to translate the existence of a long-run equilibrium between variables. Therefore, there is the possibility of distinguishing between two types of shocks, those that drive the common stochastic trend (the long-run relation), and hence have permanent effects and those which have transitory effects, temporarily driving variables outside of equilibrium. One of the features of a SVECM is the possibility to separate these shocks.

Identification à la Blanchard and Perotti: A Motivation

Departing from the identification presented in Blanchard and Perotti (2002), considered one of the most careful approaches to fiscal shocks in the context of VARs (Ramey (2011)), and the one that more easily allows to introduce cointegration, it was assumed one cointegration relation between government spending and output. Government spending, tax revenues and output are all characterized by unit roots[4], consequently, they can be represented in an error correction model. The reduced form VECM specification is:

$$\Delta X_t = \alpha_0 + \Pi X_{t-1} + \sum_{i=1}^{3} \Gamma_i \Delta X_{t-i} + u_t \tag{1}$$

where $X_t = (G_t, T_t, Y_t)$ is a three-dimensional vector of quarterly government expenditure, total tax revenue[5] and output, all in real[6] *per capita* values and in logarithms. Π is such that $\Pi = \gamma\beta'$, where γ is a matrix of loading coefficients and β is the cointegration matrix. Γ_i is a short-run coefficient matrix for $i = 1, 2, 3$. α_0 includes a constant term and seasonal dummies. Finally, $u_t = (u_t^G, u_t^T, u_t^Y)$ is a vector of reduced form residuals. The model includes 3 lags in differences decided according to the AIC criterion and to ensure no serial correlation. As stated before, it is

[4]The statistical tests can be found in the appendix.

[5]This specification differs from the one in Blanchard and Perotti (2002), which uses net tax revenues (tax revenues net of transfer payments), a definition not very common as stated in Mountford and Uhlig (2009). Transfer payments have their own effects on economic variables, which can be different from taxation. Also, in order to keep the specification as simple as possible, this variable is not included.

[6]Real variables were obtained using the GDP deflator. Blanchard and Perotti (2002) argue that the results are similar when using the own deflator.

assumed one cointegration relation between government expenditure and output with no relation concerning tax revenues. Thus, the cointegration matrix takes the form $\beta = (1, 0, \beta_3)'$.

Identification Scheme

The presence of automatic stabilizers and policy responses to economic cycles in fiscal variables creates the aforementioned problem of endogeneity. In order to overcome this issue, Blanchard and Perotti (2002) argue that the use of quarterly data allows the disentangling of automatic responses from discretionary ones. The presence of implementation lags in fiscal policy creates a window where all responses are only automatic. Regarding public expenditure[7], there is no reason to believe that there are immediate responses to output. On the other hand, this is not the case with tax revenues, as a large proportion of total tax revenues derives from income taxation.

With the purpose of removing the impact of output on tax revenues, obtaining a measure of policy responses, it is estimated what is called "cyclical adjusted tax revenues" following the early work of Giorno et al. (1995) and adapted by a series of OECD papers (Van den Noord (2000), Girouard and André (2006) and Price et al. (2015)). Considering $T_t = \delta Y_t + t'_t$, this method consists on estimating the elasticity of total tax revenues to output (δ) and using $t'_t \equiv T_t - \hat{\delta} Y_t$ as an IV to estimate tax policy shocks. Using information regarding the tax system and estimated elasticities of the different tax components (personal income tax, corporate tax, social contributions and indirect taxes), δ can be estimated using:

$$\delta = \sum_i \eta_{T_i B_i} \cdot \eta_{B_i Y} \cdot \frac{T_i}{T} \tag{2}$$

where $\eta_{T_i B_i}$ is the elasticity of tax i to its respective tax base, $\eta_{B_i Y}$ is the elasticity of the tax base of tax i to output, T_i is the total revenues of tax i and T is the total tax revenues [8].

There is no reason to account for this variable in the cointegration relation. Firstly, cointe-

[7]It is being only considered government purchases of goods and services. The same would not be true if transfer payments here included.

[8]In the appendix can be found more details on how this elasticity was estimated and the assumptions behind it. Moreover, results are robust to changes in estimated elasticities, as found by Blanchard and Perotti (2002).

gration tests show no cointegration relation between either variable and cyclically adjusted tax revenues. Moreover, the Wald Test indicates that the coefficient in the already considered cointegration equation must be zero[9]. Secondly, public debt is characterized by a unit root, which casts doubts on the possible cointegration between government spending and tax revenues[10].

As in any structural identification, structural innovations are assumed to be linked to reduced form ones through a non-singular B matrix such that:

$$u_t = B\varepsilon_t \tag{3}$$

where ε_t is a vector of serially and mutually uncorrelated shocks with unit variance.

From the previous assumptions, B is such that:

$$\begin{bmatrix} u_t^G \\ u_t^{t'} \\ u_t^Y \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & 0 \\ b_{21} & b_{22} & 0 \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_t^G \\ \varepsilon_t^{t'} \\ \varepsilon_t^Y \end{bmatrix} \tag{4}$$

One more restriction is needed in order to ensure identification: it will be assumed that $b_{12} = 0$, meaning that expenditure shocks are ordered first[11]. The identification scheme becomes very similar to a Cholesky decomposition.

Data

Data on fiscal variables, GDP and GDP deflator was obtained from the NIPA tables from the US Bureau of Economic Analysis. Government expenditure corresponds to the sum of purchases of goods and services by the government for both federal and local and state governments. Total taxation consists on the sum of total income taxation (personal and corporate), social contributions, taxes on production and imports and taxes from the Rest of the World, also at the federal and state and local governments levels, which has then been adjusted as explained before. All series were seasonally adjusted by the source.

[9]The results can be found in the appendix.

[10]Even thought, there are other sources of spending and revenue also characterized by unit roots (like transfer payments) which could be the cause, the government budget is also not a stationary variable. This indicates that sources of revenue are not cointegrated with sources of spending. Hence, it is reasonable to assume that cyclically adjusted tax revenues are not part of any cointegration relation.

[11]Another alternative would be to assume that taxation shocks are ordered first, results do not change.

Results

Figure 2 shows the estimated IRF[12] for the period of Q1-1948 to Q3-2019. Without any long-run restrictions, it is clear that spending shocks seem to have temporary effects on the variables of interest, while output shocks have permanent effects on both variables.

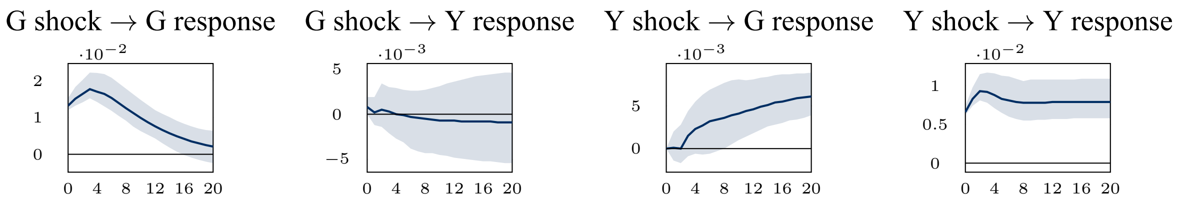

Figure 2: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping.

This illustrates the argument discussed before: shocks with permanent effects on output, which can be interpreted as TFP (total factor productivity) shocks, promote economic growth and hence increase spending in the long run. Nevertheless, this spending is targeted at improving the quality of life of citizens, not being considered fiscal policy in the sense of its usual discretionary role. At the same time, the neoclassical theory predicts that permanent increases in government spending have positive and permanent impacts on output due to permanent negative wealth effects. Presumably, the effects of the TFP shock on output may be enhanced by the response of government spending.

Separating Shocks with Temporary and Permanent Effects

The next step is formally separating the two types of shocks, and in order to achieve it equation (1) is rewritten as the following Beveridge-Nelson decomposition:

$$X_t = X_0^* + \Theta \sum_{i=1}^{t} u_i + \sum_{j=0}^{\infty} \Theta_j^* u_{t-j} \tag{5}$$

where X_0^* contains initial values and deterministics, $\Theta \sum_{i=1}^{t} u_i$ represents the stochastic trends in variables, and $\sum_{j=0}^{\infty} \Theta_j^* u_{t-j}$ collects the shocks with transitory effects.

[12]Figure 7 in the appendix presents the remaining impulse response functions.

Taking the relationship between structural and reduced form residuals in equation (3):

$$X_t = X_0^* + \Theta B \sum_{i=1}^{t} \varepsilon_i + \sum_{j=0}^{\infty} \Theta_j^* B \varepsilon_{t-j} \tag{6}$$

The matrix ΘB (matrix that collects the long-run impact of shocks) has reduced rank due to cointegration. The model in equation (1) with k endogenous variables and r cointegration relations ($rank(\Pi) = r$) implies a $rank(\Theta B) = k - r$: since some variables share a stochastic trend, r columns of ΘB are linear combinations of each other. One possibility is to set r columns of ΘB to zeros separating the shocks which only have transitory effects from the ones that have permanent effects (similar to restrictions à la Blanchard and Quah (1988)) and reduce the restrictions imposed on B itself needed to ensure identification. As a result, it is possible to distinguish r shocks with temporary effects and $k - r$ with permanent effects.

In the considered case, there is one cointegration relation, therefore only one shock with temporary effects. Departing from the results found before, the column which corresponds to government spending shocks is set to zeros, representing the shock with temporary effects on all variables. Conversely, the output shock represents a shock with permanent effects. This is just a matter of naming, as so far these transitory/permanent effects can be driven by shocks to both variables, government spending or output. The tax shock is, therefore, the second shock with permanent effects.

Another property of the ΘB matrix is r linearly dependent rows. Regardless of the identification scheme, cointegration implies a given long-run relation, i.e. after any type of shock variables will return to the condition established by the cointegration equation:

$$\beta \cdot X_t = 0 \tag{7}$$

In the current specification, the one cointegration equation simplifies to:

$$G_t + \beta_3 Y_t = 0 \Leftrightarrow \frac{G_t}{Y_t} = -\beta_3 \tag{8}$$

Consequently, the first row of ΘB is equal to the third row scaled by a constant, $-\beta_3$. As a result, the previously mentioned identification assumptions correspond to only two independent restrictions. As the identification of structural shocks requires $k(k-1)/2$ restrictions (in this case three), it will rely on the properties of the IV: cyclically adjusted tax revenues are not contemporaneously affected by output shocks. This strategy allows to remove some of the restrictions imposed before. The B and ΘB matrices are such that:

$$\begin{bmatrix} u_t^G \\ u_t^{t'} \\ u_t^Y \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & 0 \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_t^G \\ \varepsilon_t^{t'} \\ \varepsilon_t^Y \end{bmatrix} \tag{9}$$

$$\Theta B = \begin{bmatrix} 0 & \theta_{12} & \theta_{13} \\ 0 & \theta_{22} & \theta_{23} \\ 0 & \theta_{32} & \theta_{33} \end{bmatrix} \tag{10}$$

Results

Figure 3 displays the results for new identifying assumptions. “Temp” stands for the shock with temporary effects (henceforth temporary shock) and “Perm” for the previously mentioned output shock associated with permanent effects (henceforth permanent shock).

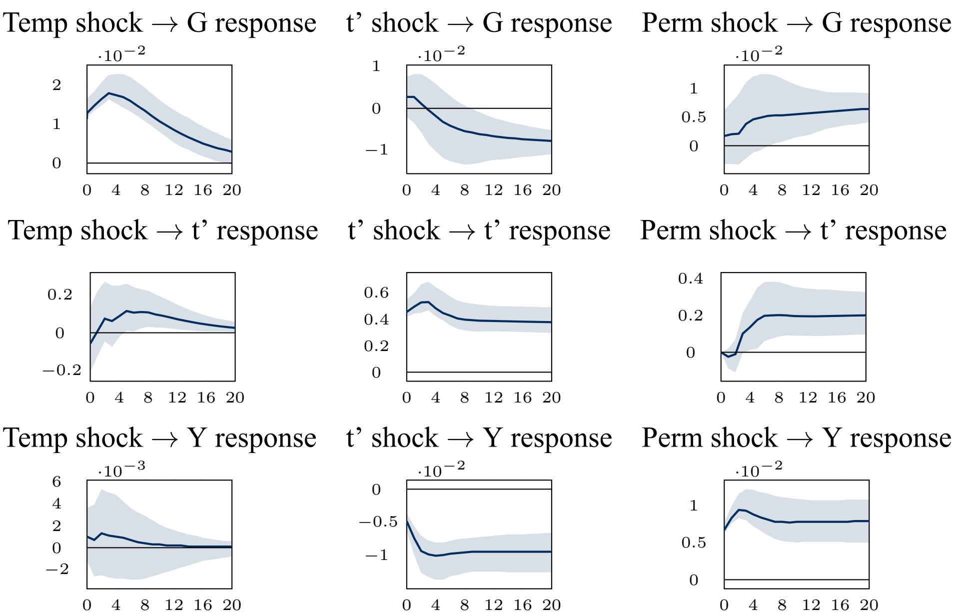

Figure 3: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping.

The temporary shock displays similar effects to what would be desirable and expectable for a stimulus package according to theory: both spending and output increase temporarily. Tax policy is affected by a fall in taxes during the first period, compensated by smaller and smaller increases afterwards. As already mentioned, the tax shock has permanent effects on all variables, and potentially because of its distortionary features it decreases output in the long run and consequently, government spending. Nonetheless, its impact is such that the cointegration relation is preserved. Finally, the permanent shock increases output, taxation and government spending both in the short and long run, being associated with a TFP shock.

These results show small differences when compared with the previous ones which raises the question of whether this shock with temporary effects is only a result of temporary changes to government spending. In order to understand if this might be true, the model is re-estimated with the additional constraint of $b_{13} = 0$[13] (the coefficient is equal to 0.0017 in the original model with a p-value of 0.502 for the null hypothesis of being equal to 0). As results do not change substantially[14], there is evidence in favour of the previous consideration. It also indicates that the assumption of Blanchard and Perotti (2002) might not be very strong, at least regarding shocks that affect the economy temporarily.

IV Identifying Government Spending Shocks

The identification scheme presented before allows to study the effect of shocks which mimic the implementation of fiscal policy with stabilization purposes: temporary changes in government spending with temporary consequences for output. This interpretation of the temporary shock allows to build on the cointegration assumption, an alternative identification scheme to analyse the impact of fiscal policy. The strategy also benefits from the separation of shocks which have

[13]This restriction also affects the impact of the shock with permanent effects as it no longer has a contemporaneous impact on output. This assumption is not very restrictive, as these shocks are associated with economic growth, and it is plausible to assume that the effect takes time to be reflected in government spending.

[14]Results can be found in the appendix in figure 8.

permanent effects on government spending as they are not associated with the stabilization role of government spending, but rather to improving the services provided by the government.

Following on several concerns with the identification of exogenous spending shocks, the model is augmented to include several variables of interest and deliver more reliable results.

Empirical Specification

Building on the previous model and still assuming only one cointegration relation between government spending and output, the empirical model has the following reduced form:

$$\Delta X_t = \alpha_0 + \Pi X_{t-1} + \sum_{i=1}^{3} \Gamma_i \Delta X_{t-i} + \zeta W_t + u_t \tag{11}$$

where $X_t = (G_t, t'_t, Y_t, D/Y, \Delta i)$ is a five-dimensional vector of quarterly government expenditure, cyclically adjusted tax revenues, output[15], debt-to-GDP ratio and nominal interest rate in first differences, $W_t = (\%\Delta G^F_{t|t-1})$ is a vector of exogenous variables, in this case, the growth rate of forecasts for government expenditure elaborated in $t-1$ for period t. Π is such that $\Pi = \gamma\beta'$, where γ is a matrix of loading coefficients and β is the cointegration matrix. Γ_i is a short-run coefficient matrix for $i = 1, 2, 3$. α_0 includes a constant term and seasonal dummies. Finally, $u_t = (u^G_t, u^{t'}_t, u^Y_t, u^{D/Y}_t, u^{\Delta i}_t)$ is a vector of reduced form residuals. Once more, the model includes three lags for endogenous variables and no lags of exogenous variables. The cointegration matrix is of the form: $\beta = ((1, 0, \beta_3, 0, 0) : (0, 0, 0, 0, 1))'$.

As argued before, financing is a key determinant in the effects of fiscal policy. A measure of tax policy was already included in the first specification as a way to control for changes in taxes at the moment of higher government spending or later on. However, as increases in public spending must be matched with higher taxes at some point in time and not necessarily at the point of higher expenditure, the restriction associated with the temporary shock not affecting tax policy in the long run will no longer be considered.

An important factor that seems to be almost always forgotten is debt. Favero and Giavazzi

[15]All as defined before: real *per capita* values and in logarithms.

(2007) found that failing to account for debt dynamics can lead to IRF that show spending expansions along unsustainable paths for the debt-to-GDP ratio. For this reason, it is important to include this series in the model (as advised in Favero and Giavazzi (2007)) since very high values may affect back fiscal policy, limiting its availability or even requiring fiscal consolidation.

Data shows that debt levels have been increasing over the past years. Barro (1979) argues that temporary increases in government spending are not reflected in taxation as an optimal policy choice in order to minimize the deadweight loss existent in tax collection. Moreover, tax revenue is adjusted simply due to reflection of automatic stabilizers. In the end, there is no reason to believe that an equilibrium for the debt-to-GDP ratio exists: it may vary freely depending on changes to the normal paths of government spending and output. These ideas seem to be consistent with the data, as units roots characterize both debt and the debt-to-GDP ratio. Following these arguments, the empirical model will not limit the long-run path of the debt-to-GDP ratio through either long-run restrictions or the imposition of cointegration.

On a different note, it would not make sense to consider any cointegration relation with the debt-to-GDP ratio as there is no reason to believe that it moves together with any of the other variables in the model. Debt is the result of more than just the difference between government spending and tax revenues, and since other components like transfers and interest payments have considerable weights on the government budget, important variables are missing so that a cointegration relation would make sense. Standard cointegration tests also point that no other cointegration relation should be considered.

The interest rate plays an important role in the transmission mechanism as above-mentioned through the work of Christiano et al. (2011) and Corsetti et al. (2013), hence its inclusion is fundamental to the model. From an empirical point a view, Rossi and Zubairy (2011) also highlight the relevance of considering monetary policy in the study of fiscal policy. The authors demonstrate that both policies have been responsible for a large part of economic fluctuations and that neglecting one of them might lead to confounding effects.

Given that the interest lies on understanding the effects of spending expansions on output, the interest rate is made stationary using first-differences[16]. Introducing stationary variables in the VECM requires an individual cointegration relation for each variable alone, as it is possible to see in the second row of matrix β.

As mentioned before, one of the major concerns with this approach is anticipated changes in government spending[17]. The neoclassical theory states that what matters for the aforementioned negative wealth effect is the expected present value of government spending and not the timing of spending. If agents expect higher government spending in the future or spending is announced beforehand, then agents will react before the actual spending takes place. With this in mind, professional forecasts of government spending made in the previous quarter are used to control for spending changes which were anticipated[18]. Although this variable could have been included as endogenous[19], it is not endogenous to any of the other variables, as expectations in the previous period are by definition not affected by current information. This procedure allows to minimize the required identification restrictions and increase degrees of freedom in the estimation. They are also included in a stationary form to avoid spurious results[20].

[16] It also eliminates problems with possible cointegration relations found in the data but not predicted by theory. Yet, results do not change if the variable is included in levels but not accounted for in any cointegration relation.

[17] Expectations are indeed one of the major problems with econometric models. Agents have access to several sources of information, and if they perceive future changes their behaviour can change before any change actually takes place. One of the possible ways to deal with this problem is to include Factors in the estimation, as suggested in Bernanke et al. (2005). This methodology would allow controlling for a greater set of information related to expectations and other variables that are important for fiscal research and that cannot be included as the degrees of freedom would decrease substantially. However, including Factors in the SVECM would not be done easily for different reasons. Firstly, it would be required the understanding of the relationship between the temporary shock and the Factors. Secondly, identification restrictions would require strong assumptions regarding output, government spending and the Factors. For these reasons, the most conservative approach was chosen.

[18] The Ramey news variable could also have been included, but given the sample reduction it would only represent two dates and the expected higher military spending seems to be captured by the professional forecasts.

[19] Results are robust to including this variable as endogenous and ordering it first so that it is not influenced by any of the other variables contemporaneously.

[20] Auerbach and Gorodnichenko (2012) also suggests this stationary form due to data revisions over time.

Identification Strategy

Intending to separate the shock with transitory effects[21] from the ones with permanent effects, the long-run impact of government spending on itself and output is set to zero ($\theta_{11} = \theta_{31} = 0$ in matrix ΘB). As discussed before, the debt-to-GDP ratio and tax policy are free of long-run restrictions. Therefore, the temporary shock has only temporary effects on government spending and output, which is enough to disentangle the shocks implicit in the cointegration relation.

Identification of the other shocks requires further restrictions[22] which are set as follows[23] and explained below:

$$\begin{bmatrix} u_t^G \\ u_t^{t'} \\ u_t^Y \\ u_t^{D/Y} \\ u_t^{\Delta i} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{bmatrix} \begin{bmatrix} \varepsilon_t^G \\ \varepsilon_t^{t'} \\ \varepsilon_t^Y \\ \varepsilon_t^{D/Y} \\ \varepsilon_t^{\Delta i} \end{bmatrix} \tag{12}$$

$$\Theta B = \begin{bmatrix} 0 & \theta_{12} & \theta_{13} & \theta_{14} & 0 \\ \theta_{21} & \theta_{22} & \theta_{23} & \theta_{24} & 0 \\ 0 & \theta_{32} & \theta_{33} & \theta_{34} & 0 \\ \theta_{41} & \theta_{42} & \theta_{43} & \theta_{44} & \theta_{45} \\ \theta_{51} & \theta_{52} & \theta_{53} & \theta_{54} & \theta_{55} \end{bmatrix} \tag{13}$$

Government spending shocks are assumed not to affect tax policy in the same period, equivalent to setting $b_{21} = 0$[24]. The properties of cyclically adjusted tax revenues, once more allow to impose that output shocks do not influence tax policy contemporaneously ($b_{23} = 0$).

The debt-to-GDP ratio is a function of current government spending, tax policy, output and interest rate, therefore any shock to these variables influences debt contemporaneously. Thus,

[21] There is only one cointegration relation, therefore only one shock with temporary effects. It follows that the remaining four have permanent effects. Remember, however, that regardless of the shock, cointegration is always preserved.

[22] As explained before the previous constraints only amount to one independent restriction.

[23] The main results are robust to a Cholesky decomposition. Additionally, as in the previous model, the coefficient b_{13} is not statistically different from zero (p-value of 0.882) and setting $b_{13} = 0$ does not change the results. Once again, this can be interpreted as output shocks not having a contemporaneous impact on government spending.

[24] As argued before, the ordering of spending versus taxes is irrelevant, results do not change considering the opposite relation. In fact, the estimated coefficients are never statistically significant. If on the contrary, it was assumed that temporary government shocks did not have a long-run impact on tax policy (setting $\theta_{21} = 0$) as argued by Barro (1979), results would not change extensively. IRF can be found in figure 10 in the appendix.

it is assumed that shocks to the debt-to-GDP ratio do not affect government expenditure, tax policy and output in the same period by setting $b_{14} = b_{24} = b_{34} = 0$. This option can be a reasonable assumption as the feedback from debt to fiscal variables takes time to build up.

It is assumed further that interest rate shocks do not to affect government spending and tax policy contemporaneously ($b_{15} = b_{25} = 0$)[25]. As long as there is no coordination between fiscal and monetary policy, it can be suitable to take government choices as exogenous to monetary policy. Nevertheless, the opposite would not be accurate as the interest rate reacts to changes in government spending or taxation through either changes in the real interest rate, expected inflation or Central Bank policy.

Aiming not to constrain the B matrix heavily and allowing the interest rate and the debt-to-GDP ratio to be affected by all other variables in the same period, the results rely on the assumption of long-run money neutrality. Under this hypothesis, changes in the nominal interest rate do not affect real variables in the long run, therefore shocks to the interest rate have no long-run impact on government spending, tax policy or output, which refers to imposing $\theta_{15} = \theta_{25} = \theta_{35} = 0$. This restriction follows the idea in Blanchard and Quah (1988), and it is widely used in monetary policy research, as noted by Ritto et al. (2019).

Data

Aside from the data sources already mentioned, the forecasts for government expenditure come from the Professional Forecasters Survey of the Federal Reserve Bank of Philadelphia. As suggested in Auerbach and Gorodnichenko (2012), given the small period where these estimates are available they were put together with the same estimates from the Greenbook projections from the Federal Reserve Board of Governors[26]. The short-run interest rate corresponds to the effective federal funds rate and was extracted from the FRED data. Finally, public debt was

[25]Note also that interest payments are not included in spending.
[26]More information about how the two series were put together can be found in the section Data of the appendix.

obtained from the OECD statistics, and it corresponds to the total debt of the general government (i.e. federal and local and state government). All series were seasonally adjusted by the source[27].

Results

Figure 4 depicts part of the results[28] for the IRF of the estimated model for the period of Q2-1970 to Q3-2019[29].

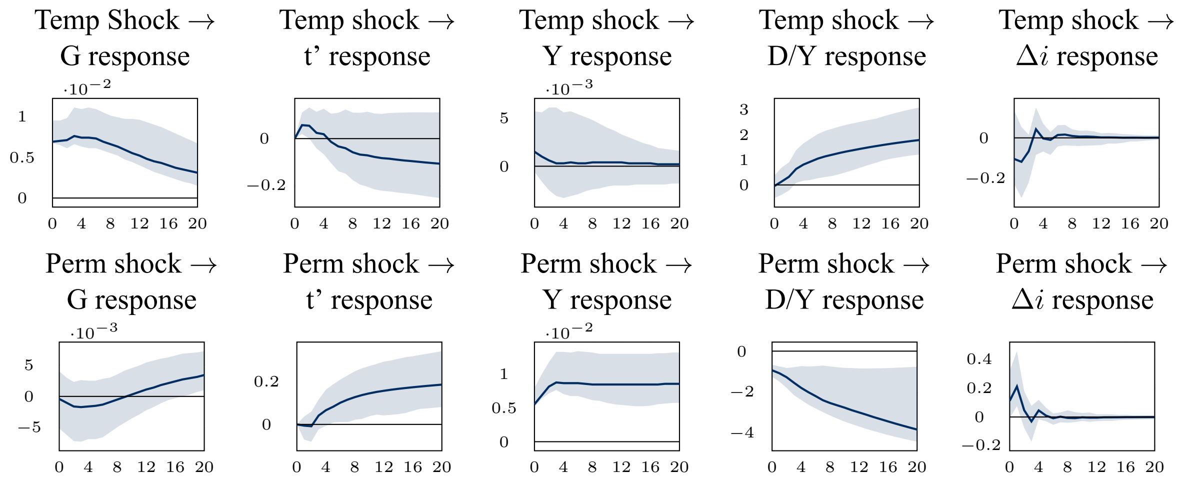

Figure 4: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable, with exception of Δi, whose response and shock is given in differences of percentages. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping.

In accordance with the previous discussion, the temporary shock (refered to as "Temp" in the results) is associated with spending shocks in the context of a stabilization fiscal policy. The "Perm" shock (named permanent shock), on the other hand, is associated with TFP and constitutes the fourth shock with permanent effects in the model. Note, once more, that all permanent shocks preserve the cointegration relation.

The temporary spending shock by construction increases government spending and output temporarily. Taxation reacts by increasing in the first periods, followed by a permanent

[27]Except for public debt and the interest rate, which were adjusted using the X13 routine provided by the US Census Bureau and implemented in Gretl.

[28]All results were obtained using the software JMuilti (see http://www.jmulti.de/). The cointegration relation was estimated using the Johansen approach, the reduced form VEC using Ordinary Least Squares and the structural form using Maximum Likelihood Estimation. Bootstrapping was done with 100 replications and using Hall Bootstrap Percentile Confidence Intervals.

[29]The remaining IRF can be found in the appendix in figure 9.

non-significant decrease. The debt-to-GDP ratio is not significantly affected during the first quarters, as a positive response from both tax policy and output means higher tax revenues. However, a year later, debt starts increasing, converging to a higher level, which is coherent with Barro (1979) arguments. The interest rate responds with a negative variation, which could be explained by an increase in expected inflation as theory predicts a positive response of the real interest rate to spending shocks[30].

These results seem to be consistent with existent literature in what concerns the direction of responses, however differences arise in their persistency. For instance, comparing the effects of the considered temporary shock with Blanchard and Perotti (2002) spending shocks allows to conclude that this results do not show as much persistence as their model in first difference. The discrepancies could be partially related to the identification assumptions and cointegration relation. Considering now the results from the augmented VAR in Ramey (2011), the behaviour of output, taxation and nominal interest rate is quite similar, yet differences in persistency are even more relevant. Ramey (2011) results show that it takes more periods for the impact to become zero and none of the variables is affected permanently.

The permanent shock is associated with TFP as it displays similar effects to that of economic growth. Also by construction, it increases output and spending permanently. However, in the short run, government spending is not very responsive reflecting a lag between economic growth and higher spending. Tax policy reacts with higher taxes, yet its presumed distortionary feature is counteracted by the positive effects of TPF on output and the increase in government spending. The debt-to-GDP ratio decreases substantially reflecting a permanently higher tax revenue and output. Finally, the nominal interest rate is affected positively by the permanent shock, which can be interpreted as the response of the Central Bank through a Taylor Rule.

[30] When considering instead the model with real interest rates using the approximation $r = i - \pi$, the negative results remain non-significant.

Spending Multipliers[31]

Computing reliable multipliers in this set up is a complicated task. As variables are in logarithms, IRF correspond to elasticities. As a consequence, in order to compute multipliers, these need to be converted back to monetary units. The traditional procedure requires IRF to be multiplied by the average value of the output-to-government-spending ratio. Ramey (2019) warns that this *ad hoc* "conversion factor" biases upwards multipliers' estimates given that the ratio is not constant over time. Other methodologies have been developed to provide more trustworthy estimates, but none of them can be applied to the specified empirical model, as they would compromise the focus on the cointegration relation. Therefore, spending multipliers are computed in the standard way:

$$\text{Spending Multiplier}_t = \frac{\sum_{i=0}^{t} \%\Delta Y_i}{\sum_{i=0}^{t} \%\Delta G_i} \cdot \frac{\bar{Y}}{G} \tag{14}$$

where $\%\Delta Y_i$ corresponds to the percent variation in output given the temporary shock, $\%\Delta G_i$ is the percent change in government spending given the same shock, $Y\bar{/}G$ is the average ratio of output-to-government-spending. Notice that for $t = 0$ it corresponds to the impact multiplier and that for $t > 0$ the result is an accumulated multiplier.

Estimated multipliers can be found in figure 5. The impact multiplier is equal to 1.35, significantly above the usual estimates, which typically range from 0.6 to 1. However, it rapidly goes below 1 after one year and a half, converging to a value around 0.4. In spite of the impact converging to zero, accumulating the consecutive effects yields permanently positive cumulative multipliers. Nevertheless, given the size of the confidence bands of the IRF, these multipliers are most likely not significantly different from zero at any horizon.

[31] The focus of this study is on the cointegration relation between output and government spending, therefore it has forgone the possibility of computing tax multipliers. Nevertheless, it is essential to note that in order to do so, the effects on cyclically adjusted tax revenues would need to be converted back to the tax revenues. Nonetheless, Riera-Crichton et al. (2016) argue that the use of cyclically adjusted tax revenues to estimate tax multipliers has several pitfalls, namely the estimated elasticities, also pointed out by Caldara and Kamps (2012). This adds up to the reasons why these multipliers were not estimated.

Robustness Checks

In this section, the robustness of the previous results is tested through changes in the sample considered. Gordon and Krenn (2010) argue that when computing multipliers the sample period plays an essential role for the relevance of the results, as they only make sense given the sample characteristics, namely different utilization of resources and present constraints.

Given data availability, the sample period does not cover major war events, which have peculiar features and must be considered carefully. Departing from previous contributions to literature, ideally the sample would be divided into three periods with the first break happening in 1980. Perotti (2005) argues that transmission mechanisms have changed considerably due to a possible structural break somewhere in the 80s. Lastly, the second break should be set in 2008 with the beginning of the Financial Crisis and of a binding zero lower bound. Nonetheless, the first and third period have very few observations, resulting in an unstable model unable to provide accurate estimates. Following on this pitfall the sample is divided in two to guarantee enough observations in each period. The sample split happens in Q3-1994.

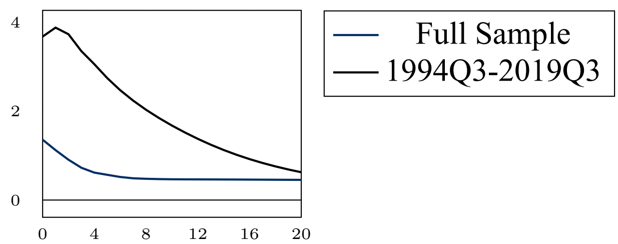

Figure 5: Cumulative Spending Multipliers

The IRF change considerably in the first part (Q2-1970 to Q2-1994) yielding imprecise and non-statistical significant estimates, and null or negative spending multipliers. These results seem to be a consequence of the cointegration relation, which was not clear at the beginning of the sample. As it would be expected, results are highly dependent on the validity of the cointegration relation. The second part of the sample (Q3-1994 to Q3-2019) provides results very close to the ones found before and an impact multiplier even greater, 3.68, as shown in figure 5. The effects of fiscal policy are also more persistent, following from a cumulative multiple greater than 1 for almost four years. This could be a result of the zero lower bound being binding for about half of this sample split.

V Conclusion

This paper explores an extension of the SVAR models used in fiscal research, providing insights on the effects of considering cointegration between government spending and output. In spite of being rarely considered, the data seems to suggest such an assumption.

Departing from the cointegration relation, one possibility is to disentangle shocks which affect temporarily government spending from those that have permanent effects. Providing an interpretation for these shocks brings forward an important feature of the data available for economic research. Government spending data is contaminated with changes resulting from the actual role of stabilisation policy and others driven by economic growth.

The shock decomposition allows the analysis to focus on "throw-in-the-ocean" government spending, as mentioned by Perotti (2011), and its stabilisation role. Findings reveal a positive, yet not significant, impact of a fiscal expansion on output, with an impact spending multiplier of 1.35 and a persistent positive cumulative multiplier.

Aside from bringing some light into a possible identification scheme not available in the standard models, it reinforces the importance of modelling choices and assumptions in the shock identification process. The conclusions taken seem to be aligned with existent literature, however they reveal differences in the persistency of responses. This finding suggest that cointegration should be accounted for when found, as it allows to better understand the persistency of the effects on economic variables. As already argued in previous studies, fiscal policy results are very often "hostages" of the identifying assumptions.

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Appendix

I Methodological Issues

I.1. Stationarity Tests

In order to test if variables are stationary[32], Augmented Dickey-Fuller Tests were used. Under the null hypothesis (H_0) the time series is not stationary. The null hypothesis can be tested against the alternative hypothesis of stationarity (with constant in the model - second column in Table 1) or of trend stationarity (with constant and trend in the model - third column in Table 1).

Augmented Dickey-Fuller Tests			
Variable	P-value (constant)	P-value (constant and trend)	Conclusion
GDP	0.9932	0.2858	Non-stationary $I(1)$
Government Expenditure	0.6909	0.1045	Non-stationary $I(1)$
Total Tax Revenues	0.9089	0.0076	Non-stationary $I(1)$ / Trend Stationary
Cyclically Adjusted Tax Revenue	0.67	0.3552	Non-stationary $I(1)$
Public Debt	0.9989	0.954	Non-stationary $I(1)$
Public Debt-to-GDP ratio	0.9371	0.9108	Non-stationary $I(1)$
Growth Rate Forecasted Government Expenditure	0	0	Stationary
Effective Federal Funds Rate	0.0928	0.155	Non-stationary $I(1)$
First Differences Effective Federal Funds Rate	0	0	Stationary
3-Month Treasury Bill	0.1878	0.4091	Non-stationary $I(1)$
First Differences 3-Month Treasury Bill	0	0	Stationary

Table 1: Results from Augmented Dickey-Fuller Tests

[32] GDP, Government Spending, Total Tax Revenues and Public Debt are defined in real per capital terms.

I.2. Cointegration Tests

With the purpose of better understanding the long-run relationships between the variables, several cointegration tests were conducted, namely the Trace Test and the Maximum Eigenvalue Test. Both test a sequence of null hypothesis such that $H_0 : rank(\Pi) = p$ and $H_1 : rank(\Pi) = p + 1$, para $p = 0, 1, ..., K - 1$. Table 2 shows the results of the tests .

Cointegration Tests				
Variables	H_0	P-value Trace Test	P-value Maximum Eigenvalue Test	Cointegration Relations
GDP Government Expenditure	$p = 0$ $p = 1$	0.0002 0.1826	0.0002 0.1826	$rank(\Pi) = 1$ 1 equation
GDP Cyclically Adjusted Tax Revenue	$p = 0$ $p = 1$	0.1588 0.1292	0.2353 0.1292	$rank(\Pi) = 0$
GDP Debt-to-GDP ratio	$p = 0$ $p = 1$	0.9093 0.7492	0.8773 0.7492	$rank(\Pi) = 0$
Government Expenditure Cyclically Adjusted Tax Revenue	$p = 0$ $p = 1$	0.0099 0.0071	0.0871 0.0071	$rank(\Pi) = 2$ $rank(\Pi) = 0$
Government Expenditure Debt-to-GDP ratio	$p = 0$ $p = 1$	0.3299 0.0437	0.7001 0.437	$rank(\Pi) = 0$
Cyclically Adjusted Tax Revenue Debt-to-GDP ratio	$p = 0$ $p = 1$	0.7611 0.61	0.7197 0.61	$rank(\Pi) = 0$
GDP Government Expenditure Cyclically Adjusted Tax Revenue	$p = 0$ $p = 1$ $p = 2$	0.0039 0.2931 0.2686	0.0036 0.3194 0.2686	$rank(\Pi) = 1$ 1 equation
GDP Government Expenditure Debt-to-GDP ratio	$p = 0$ $p = 1$ $p = 2$	0.0398 0.7475 0.6759	0.0131 0.6934 0.6759	$rank(\Pi) = 1$ 1 equation
GDP Cyclically Adjusted Tax Revenue Debt-to-GDP ratio	$p = 0$ $p = 1$ $p = 2$	0.7175 0.8829 0.9735	0.5793 0.8329 0.9735	$rank(\Pi) = 0$
Government Expenditure Debt-to-GDP ratio Cyclically Adjusted Tax Revenue	$p = 0$ $p = 1$ $p = 2$	0.392 0.4777 0.2226	0.4918 0.5627 0.2226	$rank(\Pi) = 0$

Variables	H_0	P-value Trace Test	P-value Maximum Eigenvalue Test	Cointegration Relations
GDP	$p = 0$	0.1394	0.1103	$rank(\Pi) = 0$
Government Expenditure	$p = 1$	0.6588	0.6797	
Cyclically Adjusted Tax Revenue	$p = 2$	0.5444	0.4799	
Debt-to-GDP ratio	$p = 3$	0.6475	0.6475	

Table 2: Results from Cointegration Tests

I.3. Wald Tests

With the goal of understanding which variables should be included in the cointegration relation the following Wald Test were performed. The null hypothesis (H_0) of the Wald Test is $\beta_k = 0$ in the cointegration relation against the alternative hypothesis (H_1) of $\beta_k \neq 0$ in the cointegration relation.

Wald Test for the exclusion of variables from cointegration relation			
Variables in the Cointegration Relation	Excluding	P-value	Conclusion
GDP Government Expenditure Cyclically Adjusted Tax Revenue	Cyclically Adjusted Tax Revenue	0.3974	Exclude
GDP Government Expenditure Debt-to-GDP ratio	Debt-to-GDP ratio	0.0514	Exclude
GDP Government Expenditure Cyclically Adjusted Tax Revenue Debt-to-GDP	Cyclically Adjusted Tax Revenue	0.1409	Exclude
GDP Government Expenditure Cyclically Adjusted Tax Revenue Debt-to-GDP	Debt-to-GDP	0.0521	Exclude
GDP Government Expenditure Cyclically Adjusted Tax Revenue Debt-to-GDP	Cyclically Adjusted Tax Revenue, Debt-to-GDP	0.0704	Exclude

Table 3: Results from Wald Test

I.4. Estimating the Elasticity of Total Tax Revenue to Output

In order to estimate the required elasticities to compute δ (the elasticity of taxes with respect to output) from equation (2), it was followed the work of Giorno et al. (1995), updated by Van den Noord (2000), Girouard and André (2006) and Price et al. (2015), mimicking Blanchard and Perotti (2002) and Perotti (2005). These papers are part of series of OECD papers estimating output-gaps and cyclical adjusted fiscal budgets, for which tax elasticities are required. The most recent paper corrects some mistakes made in the previous ones and accounts from recent changes in the tax system and representative consumer and for self-employed individuals (among other assumptions), as a result it constitutes the paper with the most reliable estimates.

The total amount of taxes is divided into four major categories: Indirect Taxes, Personal Income Tax, Social Contributions and Corporate Tax. For each of the taxes it is needed its elasticity to the tax base ($\eta_{T_i B_i}$), which depends highly on the tax codes and therefore extracted from the aforementioned papers and the elasticity of the tax base to output ($\eta_{B_i Y}$) which is estimated empirically.

Below can be found the assumptions made and the table with the estimates for elasticities, as well as the graph with the computed cyclically-adjusted tax revenues.

1. **Indirect Taxes**

   - Tax Base: GDP
   - Collection Lag: 0
   - Quarter Dependence: 0
   - Elasticity of Tax to Tax Base: OECD paper
     - Period 1947-1992: $\eta_{T_i B_i} = 1$ Giorno et al. (1995)
     - Period 1992-1999: $\eta_{T_i B_i} = 0.9$ Van den Noord (2000)

- Period 1999-2005: $\eta_{T_iB_i} = 1$ Girouard and André (2006)
- Period 2005-2019: $\eta_{T_iB_i} = 1$ Price et al. (2015)

- Elasticity of Tax Base to Output: 1 (tax base is equal to GDP)

2. **Personal Income Tax**

- Tax Base: Earnings
- Collection Lag: 0
- Quarter Dependence: 0

Total personal income tax revenue is derived according to the following equation (from Van den Noord (2000)):

$$T_{PIT} = t(W)W(E)E(Y) \tag{15}$$

where t is the tax rate, W is wage, E is employment and Y is GDP.

Totally differentiating this equation leads to:

$$dT_{PIT_t} = \frac{\partial t}{\partial W_t}dW_t + \frac{\partial W_t}{\partial E_t}dE_t + \frac{\partial E_t}{\partial Y_t}dY_t \tag{16}$$

Simplifying, leads to:

$$dT_{PIT_t} = \left[\left(\frac{\partial t}{\partial W_t} + 1\right)\frac{\partial W_t}{\partial E_t} + 1\right]\frac{\partial E_t}{\partial Y_t} \tag{17}$$

Reordering:

$$\eta_{T_iB_i} = \frac{\frac{\partial W_t}{\partial E_t} \cdot \frac{\partial t}{\partial W_t} + 1}{\frac{\partial W_t}{\partial Y_t} + 1} \qquad \eta_{B_iY} = \frac{\frac{\partial E_t}{\partial Y_t}}{\frac{\partial W_t}{\partial E_t} + 1} \tag{18}$$

- Elasticity of Tax to Earnings: OECD paper
  - Period 1947-1992: $\eta_{T_iB_i} = 2.5$ Giorno et al. (1995)
  - Period 1992-1999: $\eta_{T_iB_i} = 1.3$ Van den Noord (2000)
  - Period 1999-2005: $\eta_{T_iB_i} = 1.65$ Price et al. (2015) (given updates)
  - Period 2005-2019: $\eta_{T_iB_i} = 1.64$ Price et al. (2015)

- Elasticity of Earnings to Employment: lag 0 of a regression of log change of wages on first lead and lags 0-4 of log change of employment

- Elasticity of Employment to Output: lag 0 of regression of log of employment on first lead and 0-4 lags of log of output [33]
- Note: It is assumed the same elasticity for employees and for self-employed in all papers with the exception of Price et al. (2015)

3. **Social Contributions**

- Tax Base: Earnings
- Collection Lags: 0
- Quarter Dependence: 0

The approach is exactly the same as the one used for personal income tax.

- Elasticity of Tax to Earnings: OECD paper
  - Period 1947-1992: $\eta_{T_i B_i} = 0.8$ Giorno et al. (1995)
  - Period 1992-1999: $\eta_{T_i B_i} = 0.9$ Van den Noord (2000)
  - Period 1999-2005: $\eta_{T_i B_i} = 0.85$ Price et al. (2015) (given updates)
  - Period 2005-2019: $\eta_{T_i B_i} = 0.85$ Price et al. (2015)
- Note: It is assumed the same elasticity for employees and for self-employed in all papers with the exception of Price et al. (2015)

4. **Corporate Tax**

- Tax Base: Profits
- Collection Lags: Yes
- Quarter Dependence: Yes
- Elasticity of Tax to Tax Base:

[33] The data was obtained from the NIPA tables of the Bureau of Economic Analysis

- Period 1947-1992: $\eta_{T_i B_i} = 0.85$ Blanchard and Perotti (2002), the authors argue that due to collection lags, the elasticity is lower that 1 (from Giorno et al. (1995)).
- Period 1992-1999: $\eta_{T_i B_i} = 1$ Van den Noord (2000), where it was assumed that taxes were proportional to the tax base
- Period 1999-2005: $\eta_{T_i B_i} = 1$ Girouard and André (2006), keeping previous assumptions
- Period 2005-2015: $\eta_{T_i B_i} = 3.45$ Price et al. (2015), the authors argue that the proportionality assumption is not valid due to collection lags and deduction of past losses

• Elasticity of Tax Base to Output: lag 0 of a regression of log change of profits on first lead and 0-4 lags of log changes of output

In Table 4 can be found the estimated elasticities, which were obtained as explained above. Putting all together, δ is estimated using weighted averages of the previous values. The reason for this choice lies on ensuring a smooth series for the IV, as applying the previous elasticities results on a variable with significant ups and downs every time another estimate is used. However, when comparing the results from both variables, they share the same patters overtime. Afterwards, the IV is obtained using $t'_t = T_t - \delta_t Y_t$, letting δ vary across time [34]. The idea is to guarantee that each elasticity is weighted by the correct proportion that the tax takes in each quarter and is correctly reflected in each period output. The resulting IV is represented in below in Figure 6.

[34] This differs from Blanchard and Perotti (2002) which consider an average value of δ.

Estimated Elasticities					
Period	1947-1992	1992-1999	1999-2005	2005-2019	Weighted Average
Indirect Taxes					
$\eta_{T_iB_i}$	1	0.9	1	1	0.99
η_{B_iY}	1	1	1	1	1
η_{T_iY}	1	0.9	1	1	0.99
Personal Income Tax					
$\eta_{T_iB_i}$	2.19	0.50	3.38	4.12	2.35
η_{B_iY}	0.13	0.32	-0.02	0.05	0.11
η_{T_iY}	0.29	0.16	-0.08	0.19	0.26
Social Contributions					
$\eta_{T_iB_i}$	1.26	0.59	2.25	2.55	1.41
η_{B_iY}	0.13	0.32	-0.02	0.05	0.11
η_{T_iY}	0.16	0.19	-0.05	0.12	0.16
Corporate Tax					
$\eta_{T_iB_i}$	0.85	1	1	3.45	1.40
η_{B_iY}	4.32	0.80	3.21	6.34	4.35
η_{T_iY}	3.67	0.80	3.21	21.89	6.11

Table 4: Elasticities estimated for different periods

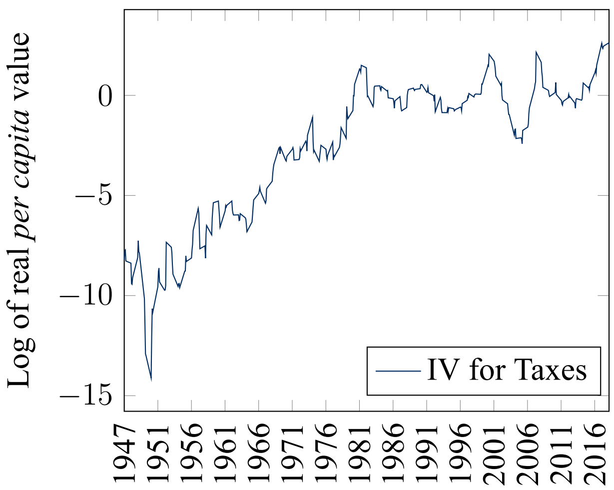

Figure 6: US Cyclically Adjusted Tax Revenues

Ideally, there would be more estimates available for different periods, which would allow to better model the way elasticities change over time and better infer on the consequences of tax changes on GDP. Note, however, that changes to the estimates have little impact on the results found, just as found in Blanchard and Perotti (2002).

II Further Results

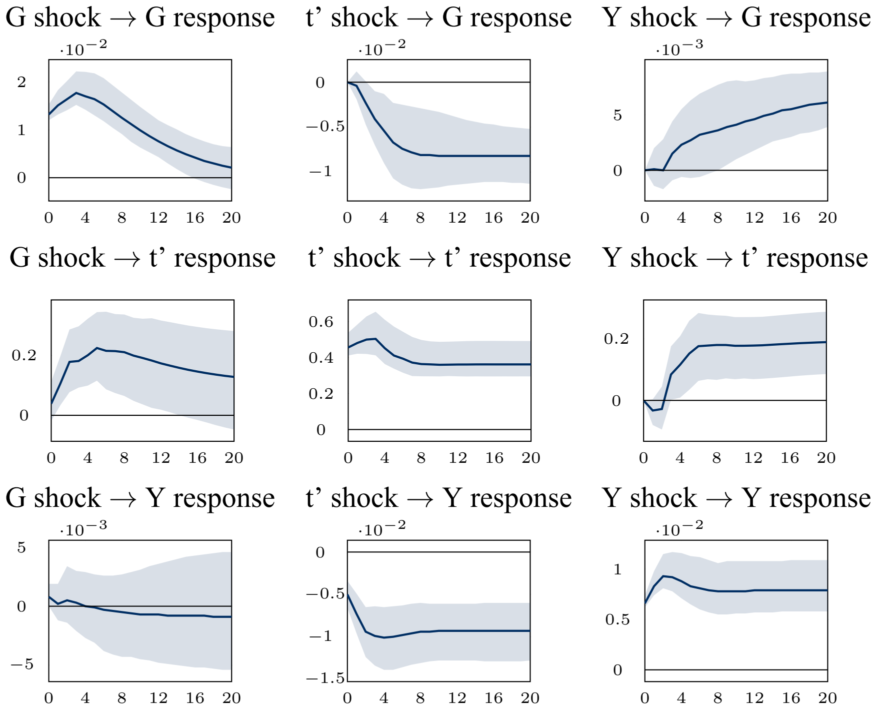

Figure 7: Impulse Response Functions

he figures show impulse response functions in percentage to 1% increase in the respective variable, with exception of Δi, whose response and shock is given in differences of percentages. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping. The results correspond to the adapted Blanchard and Perotti (2002) model, only with short-run restrictions.

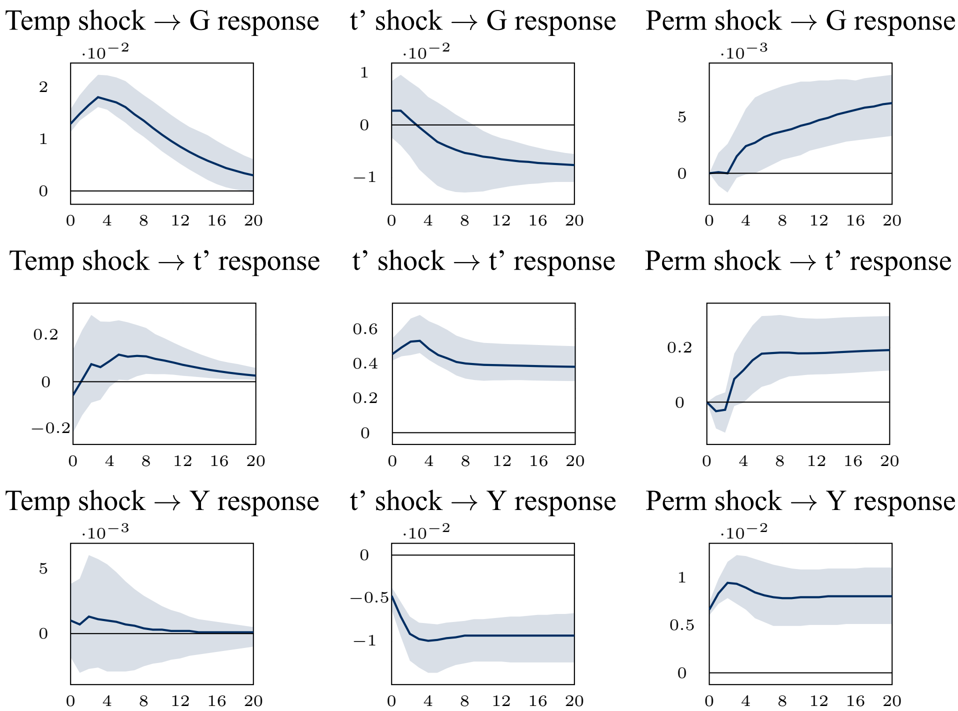

Figure 8: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping. The results correspond to the adapted Blanchard and Perotti (2002), model with long-run restrictions and overidentified to understand the role of output shocks on the temporary shock.
“Temp” stands for the shock which has temporary effects on all variables. “Perm” stands the shock which is associated to TFP shocks.

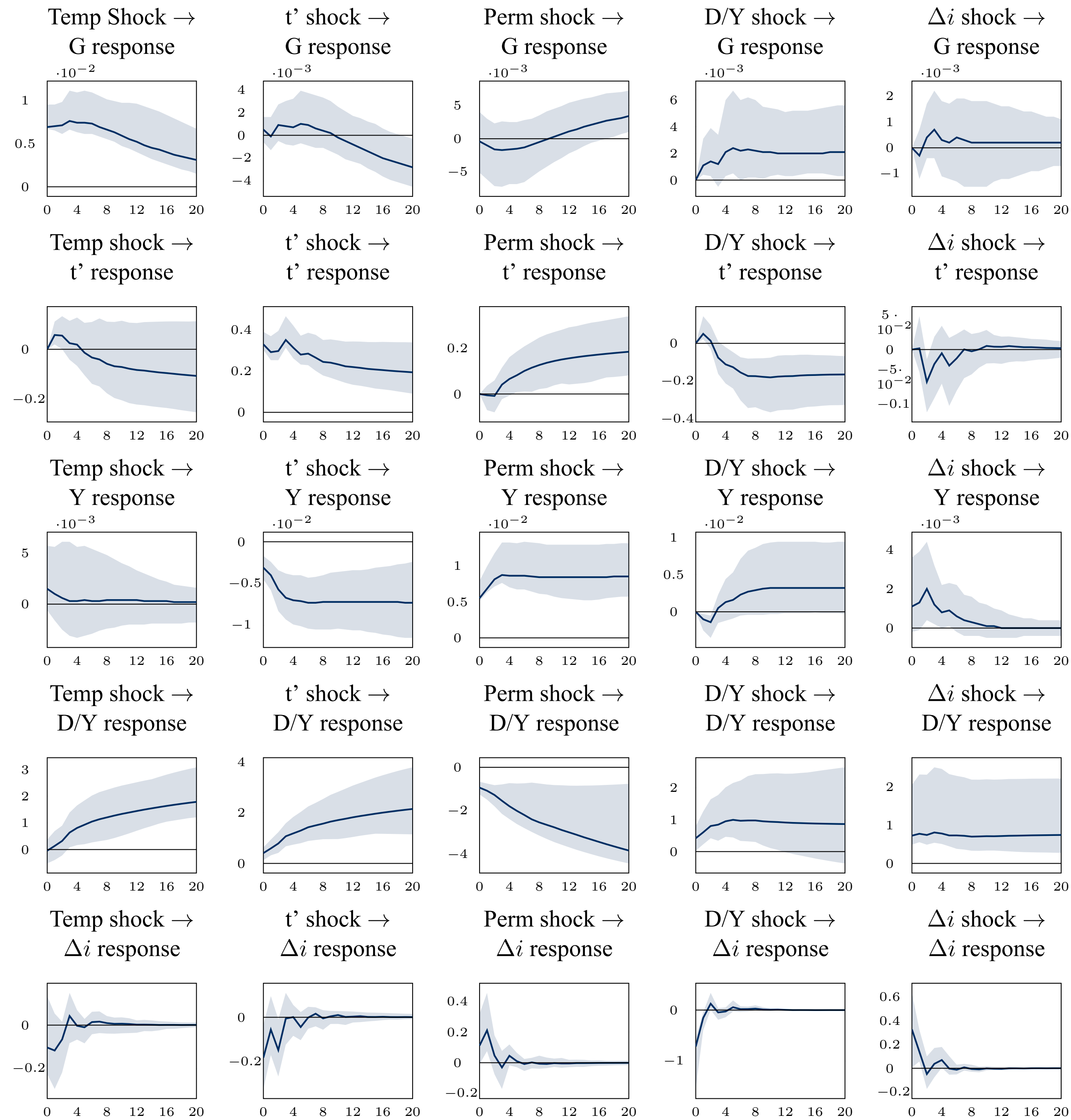

Figure 9: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable, with exception of Δi, whose response and shock is given in differences of percentages. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping.

The results correspond to the empirical model.

"Temp" stands for the shock which has temporary effects on both output and government spending. "Perm" stands for the shock associated with TFP shocks.

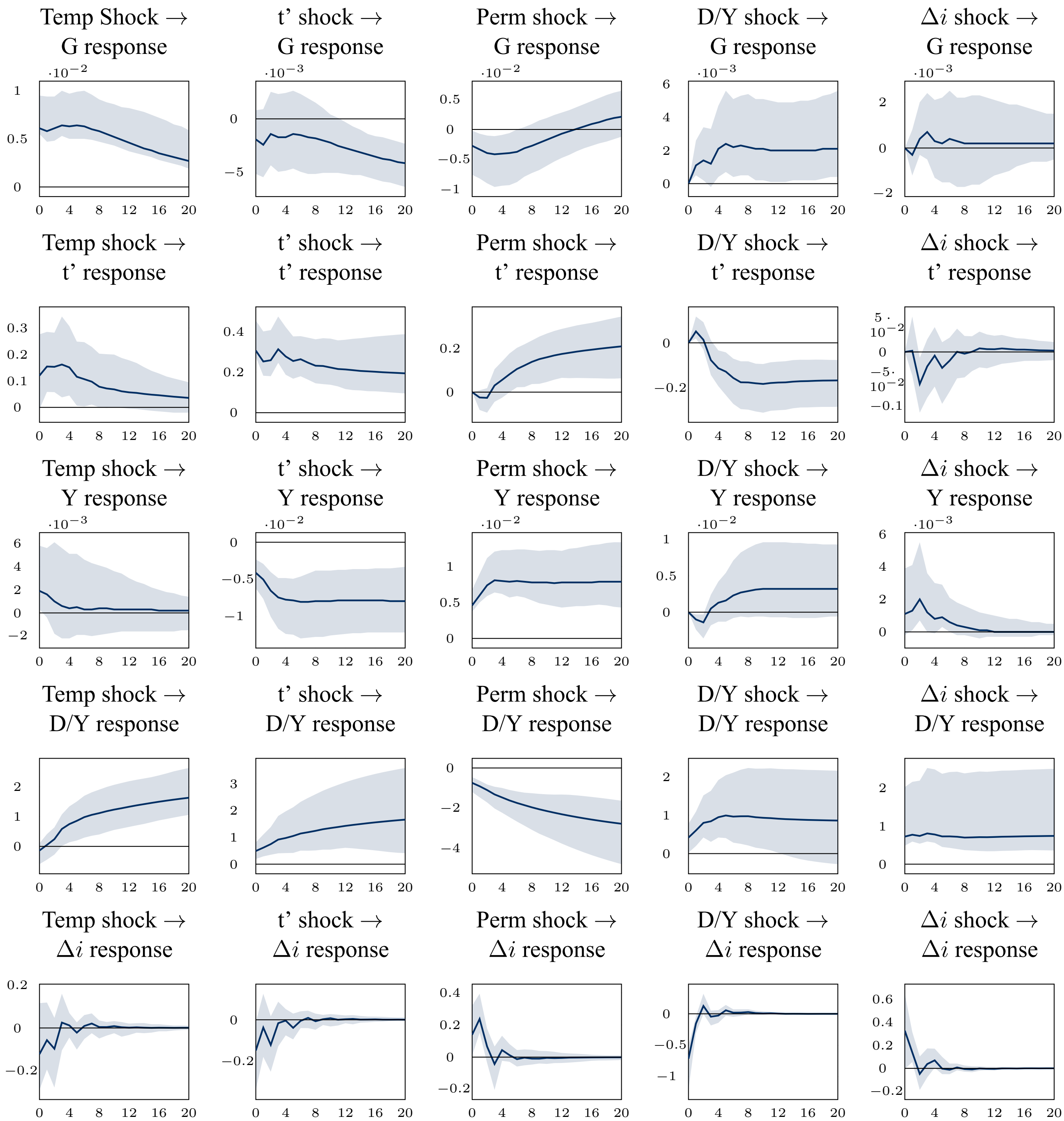

Figure 10: Impulse Response Functions

The figures show impulse response functions in percentage to 1% increase in the respective variable, with exception of Δi, whose response and shock is given in differences of percentages. Shaded areas correspond to 95% confidence intervals obtained using bootstrapping.

The results correspond to the empirical model where it is imposed that temporary shock do not have permanent effects on taxation. "Temp" stands for the shock which has temporary effects on both output and government spending. "Perm" stands for the shock associated with TFP shocks.

III Data

Variable	Period	Source	Table/Series Code
3-Month Treasury Bill: Secondary Market Rate	1947Q1-2019Q3	Federal Reserve Economic Data	Series [TB3MS], quarterly average
Contributions for Government Social Insurance	1947Q1-2019Q3	Bureau of Economic Analysis	Table 3.1. Government Current Receipts and Expenditures
Effective Federal Funds Rate	1954Q2-2019Q2	Federal Reserve Economic Data	Series [FEDFUNDS], quarterly average
Employment	1948Q1-2019Q3	Federal Reserve Economic Data	Series [CE16OV]
Forecasted Real Government Consumption Expenditure and Gross Investment Growth	1981Q3-2019Q4	Survey of Professional Forecasters	
Forecasted Real Government Consumption Expenditure and Gross Investment Growth	1966Q1-1981Q2	Greenbook projections from the Board of Governors	
GDP	1947Q1-2019Q3	Bureau of Economic Analysis	Table 1.1.5. Gross Domestic Product
GDP deflator	1947Q1-2019Q3	Bureau of Economic Analysis	Table 1.1.9. Implicit Price Deflators for Gross Domestic Product
Government Expenditure and Gross Investment (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 1.1.5. Gross Domestic Product
Government Expenditure and Gross Investment deflator	1947Q1-2019Q3	Bureau of Economic Analysis	Table 1.1.9. Implicit Price Deflators for Gross Domestic Product
Personal Current Taxes (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 3.1. Government Current Receipts and Expenditures
Population	1947Q1-2019Q3	Federal Reserve Economic Data	Series [B230RC0Q173SBEA]
Profits before Taxes (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 2.1. Personal Income and Its Disposition
Public Debt (General Government)	1952Q1-2019Q3	OECD Statistics	
Taxes from the Rest of the World (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 3.1. Government Current Receipts and Expenditures
Taxes on Corporate Income (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 3.1. Government Current Receipts and Expenditures
Taxes on Production and Imports (Federal, state and local)	1947Q1-2019Q3	Bureau of Economic Analysis	Table 3.1. Government Current Receipts and Expenditures
Wages and Salaries	1947Q1-2019Q3	Bureau of Economic Analysis	Table 2.1. Personal Income and Its Disposition

Table 5: Data Sources

Series	Notes
• 3-Month Treasury Bill: Secondary Market Rate • Forecasted Real Government Consumption Expenditure and Gross Investment Growth • GDP • GDP deflator • Government Expenditure and Gross Investment • Government Expenditure and Gross Investment deflator • Personal Current Taxes, Profits before Taxes • Taxes from the Rest of the World • Taxes on Corporate Income • Taxes on Production and Imports • Wages and Salaries	Seasonally Adjusted by the Source
• Contributions for Government Social Insurance • Effective Federal Funds Rate • Employment • Population • Public Debt	Seasonally Adjusted using X-13-ARIMA-SEATS implemented in Gretl (provided by the US Census Bureau)
• Forecasted Real Government Consumption Expenditure and Gross Investment Growth	Survey of Professional Forecasters and Greenbook projections series were put together, given that they are produced in the same way. Greenbook projections were taken from the middle of the quarter to be in the same time period of the ones from the Survey of Professional Forecasters; Due to different base years, the implicit deflator (also forecasted) was used obtain the real growth. When there was lack of data forecast data available the real implicit deflator was used.

Table 6: Notes on Data